

## **Description**

### **Technical Field**

The invention relates to a method and a device for determining a change in the heat value of a gas mixture according to the preamble of claims 1 or 6.

The method and the device are suitable in particular for on-line heat value determination in the control of gas turbines in the power station field.

### **State of the art**

For optimisation of the process technology and hence for the control of gas turbines, very precise knowledge of the process parameters is necessary. In the case of gas turbines, in a first approximation, a constant air mass flow rate in a combustion chamber is assumed so that the thermal energy which is responsible for the shaft output and hence for the power output of a power station is adjusted solely via the quantity of fuel. In modern industrial gas turbines, the optimum operating point is close to the lean extinguishing limit of the adiabatic flame temperature at which the flame is still able to stabilise itself. This adiabatic flame temperature depends inter alia upon the heat value of the fuel.

Natural gas is normally used as fuel. The natural gas supplied by the gas supplier is however subject to great variations in quality and hence in its calorific value or heat value. These variations are caused in that simultaneously natural gas is supplied from various sources, the mixture ratio being able to vary greatly according to the supply.

Variations of this type impair the function of the gas turbine in its efficiency, in the stability of the combustion and also in its toxic emissions. In extreme cases, the result has even been damage to plants.

In order to optimise the process technology, heat value measuring methods are therefore used which determine the calorific value of the supplied fuel at regular intervals and convey these to a control unit. Calorimeters or gas chromatographs are normally used for this purpose. In addition to their relatively high cost and their high maintenance requirement, these have the disadvantage that they allow merely intermittent measurement.

DE-A-4 118 781 discloses a method and a device for combustion-free determination of the calorific value of a gas. For this purpose, the mass flow rate is determined in a mass flowmeter, the volume flow rate in a volume flowmeter and the pressure difference in a further measuring means. The calorific value is calculated therefrom with the help of an approximation function when the absolute pressure is known and when the gas temperature is known.

EP-A-0 469 649 discloses a device for determining the heat value with a volume flowmeter which determines the volume flow rate by means of the pressure difference between laminar flow elements. A thermal mass flowmeter is disposed in series with the volume flowmeter in order to determine the mass flow rate.

In addition, a thermometer is present in order to determine the current gas temperature and a manometer in order to measure the absolute pressure. The pressure difference is calculated inter alia by means of these measurement values, the heat value being produced therefrom in inverse proportionality.

These two methods are relatively complex and the associated measuring devices correspondingly expensive.

### **Presentation of the invention**

It is therefore the object of the invention to produce a method and a device for determining a change in heat value of a gas mixture, which are simple and economical but nevertheless allow on-line measurement of the change.

A method and a device having the features of patent claim 1 or 6 achieve this object.

According to the invention, a measurement signal of a sensor is determined at a constant throughflow rate. The change in measurement signal is a measure of the change in the heat or calorific value of the gas mixture. As a result, a temporal change in heat value can be detected simply and this measurement signal can be used to control plants.

In particular, this method according to the invention and the associated device are suitable for use in the control of gas turbines. However they can be used also in other fields of gas combustion of the chemical and petrochemical industry, likewise in fuel cells and for controlling heterogeneous-catalytic reactions.

In a preferred variant of the method, the mass flow rate is kept constant. In a second preferred variant, the volume flow rate is kept constant, a density of the gas mixture is measured in the volume flow and the mass flow rate is determined therefrom.

In a preferred embodiment, the device for determining a change in the heat value of a gas mixture is designed as a mass flowmeter. In a

further preferred embodiment, the device is designed as an energy flowmeter.

In a preferred embodiment, the device has a throughflow sensor, as is described in the German patent application no. 199 08 664.8 and the still unpublished European patent application no. 008100511.6.

Further advantageous variants of the method and advantageous embodiments emerge from the dependent patent claims.

### **Brief description of the drawings**

The subject of the invention is explained subsequently with reference to a preferred embodiment which is represented in the accompanying drawings. There are shown:

Figure 1a a schematic representation of a part of a gas pipe having a device according to the invention for determining the heat value change in a gas in a low pressure system;

Figure 1b in a high pressure system and

Figure 2 a comparison of a deviation of monthly averages of heat values of natural gas and corresponding measurement value changes in the gas meter according to the invention with a constant throughflow rate.

### **Ways to implement the invention**

A gas pipe is illustrated in Figure 1 which is provided with a device according to the invention for determining a change in the heat value of a gas mixture. The gas pipe comprises a main conduit pipe 1 which is connected to a plant, not shown here, for example to a gas turbine.

Normally a gas mixture flows through the main conduit pipe 1 with a temporally varying composition, in particular natural gas. The method according to the invention and the device function best with hydrocarbon-containing gas mixtures, the main components of which are preferably methane, propane and ethane.

A measurement pipe 2 branches off from the main conduit pipe 1. The measurement pipe 2 normally has a substantially smaller cross-section than the main conduit pipe 1.

A distinction is made between low pressure systems with a pressure up to 2 bar in the main conduit pipe and high pressure systems with a pressure from 2 bar. In the case of low pressure systems, as represented in Figure 1a, the following elements are disposed in the measurement pipe 2 in the flow direction through the measurement pipe 2: a heat value sensor 4, optionally a density sensor 7, a sonic nozzle 5 and a pump 6. The sonic nozzle 5 serves to keep the mass flow rate through the measurement pipe 2 constant. The pump 6 pumps gas through the measurement pipe 2 preferably at a throughput of at least approx. 0.2 l/min, to a buffer volume 8. The pressure difference between the pressure in the buffer volume  $p_8$  and the fuel pressure in the main conduit pipe  $p_{\text{fuel}}$  is always substantially greater than the critical pressure of the sonic nozzle 5. It is ensured as a result that a constant mass flow rate always flows through the heat value sensor. The pump 6 operates at constant output, the pressure in the buffer container 8 is kept constant by a pressure control valve 3 in that excess measurement gas is directed back into the main conduit pipe through a bypass pipe 20. Since the measurement gas is not chemically changed when flowing through the heat value sensor, it can be directed back into the main conduit pipe 1 after flowing through the measuring path. The possibility also exists optionally, as represented in Figure 1b, of oxidising the measurement gas in an oxidation device 9 over a catalytic converter or a flame and thus avoiding the risk of explosion. In this

case, the measurement pipe terminates open at its end remote from the main conduit pipe 1 and emits therefore the gas mixture into the environment. Paladium oxide (PdO) is used for example as catalyst.

In the case of high pressure systems, as represented in Figure 1b, the following elements are disposed in the measurement pipe 2 in the flow direction through the measurement pipe 2: a sonic nozzle 5, optionally a density sensor 7 and a heat value sensor 4. A pump is necessary here only if the difference between fuel pressure  $p_{\text{fuel}}$  and atmospheric pressure is not greater than the critical pressure  $p_{\text{crit}}$  of the sonic nozzle 5. If a pump is not used for the pressure increase, then the measurement gas cannot be guided back into the main conduit pipe 1. In this case, the measurement gas is oxidised in an oxidation device 9 homogeneously or heterogeneously-catalytically.

The heat value sensor 4 measures the diffusivity of the throughflowing gas. The diffusivity is defined as

$$\alpha = \frac{\kappa}{c_p \cdot p}$$

In a preferred embodiment, the sensor 4 has at least two temperature sensors which are disposed in succession in the flow direction, a heating element disposed therebetween and measuring means for determining the heat value from the sensor signal values of the temperature sensors. This preferably concerns a throughflow sensor, as is described in the initially mentioned German patent application no. 199 08 664.8 and the still unpublished European patent application no. 008100511.6. The content of these two patent applications is a component of this application.

In a first variant of the method, the diffusivity is measured by means of the heat value sensor. Although the mass flow rate of the gas in the measurement pipe 2 is kept constant as a result of the sonic nozzle 5, the sensor signal which is obtained and hence the measured diffusivity

vary with time. This change in sensor signal, as was recognised already in the still unpublished European patent application no. 008100511.6, is caused by a change in the calorimetric value or heat value of the throughflowing gas.

This dependency is represented in Figure 2, a deviation in percentage of monthly averages of the heat values of natural gas being shown in Figure 2 during one year. This deviation is designated with  $\Delta h$ . As is evident, the heat value varies by approx. 2%. Likewise illustrated and designated with  $\Delta S$  is a change in the sensor signal value  $S$ , the sensor signal value  $S$  having been obtained by means of the above-described sensor 4. It is evident that the sensor signal value  $S$  changes in the same direction as the heat value. The reason for the fact that the dependency is not entirely proportional resides in the fact that the specific heat values of ethane and propane in relation to methane are greater than the corresponding signal excesses and in that the changing proportions of non-combustible gas components, in particular of nitrogen, do not cause a signal change.

According to the invention, this effect is now used in that the throughflow rate of the gas mixture through the heat value sensor 4 is kept constant and the changing sensor signal value which is obtained is compared with a calibrating sensor signal value which was produced during calibration of the measuring device by a calibration gas with a known heat value. Preferably, a gas mixture is chosen as calibration gas which has a composition corresponding to the average composition at the provided place of use. The difference of the sensor signal value and hence of the measured diffusivity from the calibration value is a measure of the deviation of the heat value of the measurement gas to be determined from the heat value of the calibration gas. The difference is essentially proportional to the change in heat value.

The above-described heat value sensor 4 now makes several variants of the method possible, according to the type of calibration thereof:

In a first variant of the method according to the invention, the measurement gas mass flow rate is kept constant, this being effected with the above-mentioned sonic nozzle 5. The heat value sensor 4 is calibrated to a specific, constant mass flow rate so that the measurement signal which is obtained indicates the change in diffusivity. The heat value sensor is calibrated in a simple manner with a calibration gas in that, in a first step, the sensor signal  $S(m, C_0)$  of a datum gas, e.g. nitrogen ( $N_2$ ) is determined. In a second step, a sensor signal  $S(m, C)$  for an average gas mixture as reference gas is determined and, in a third step, an amplification factor  $F$  is calculated therefrom:

$$F = \frac{S(\dot{m}, C_0)(h(C) - h(C_0))}{h_u(C_0)(S(m, C) - S(m, C_0))}$$

$h(C_0)$  being the heat value of the calibration gas and  $h(C)$  the heat value of the reference gas.

Thanks to this calibration, the relative heat value change  $\Delta h(t)$  now is a percentage as follows:

$$\Delta h(t) = \frac{S(m, C(t)) - S(m, C_0)}{S(m, C_0)} \cdot F$$

$S(m, C(t))$  being the sensor signal value which is obtained at the time  $t$  of the gas to be analysed. The sensor signal is proportional to the diffusivity in the measurement gas and hence to the composition thereof which determines the heat value.

In a second variant of the method, the density of the fuel is determined in addition, the density sensor 7 for example being used here. As density sensor 7, in particular a sensor with two quartz resonators, is suitable, as is described in EP-A-0 582 045. By means of these two



measured values, the sensor signal value and the density which are proportional to the diffusivity, the accuracy of the system is increased.

In a further preferred embodiment of the invention, the throughflowmeter is calibrated to energy flow rate, in turn the mass flow rate through the measurement pipe also being kept constant here.

The method according to the invention and the device according to the invention allow simple and economical quantitative determination of a heat value change.

**Reference number list**

1	Main conduit pipe
2	Measurement pipe
20	Bypass pipe
3	Pressure control valve
4	Heat value sensor
5	Sonic nozzle
6	Pump
7	Density sensor
8	Pressure buffer
9	Oxidation device
$\Delta h_u$	Deviation of monthly averages
$S$	Sensor signal
$\Delta S$	Change in sensor signal $S$

**Patent claims**

1. Device for determining a change in the heat value of a gas mixture,  
**characterised in that**  
the diffusivity of the gas mixture is measured with a constant, predefined throughflow rate and  
in that the measured diffusivity is compared with the reference value of a calibration gas with a known heat value, a deviation of the measured diffusivity from the reference value being a measure of the change in the heat value of the gas mixture.
2. Method according to claim 1, **characterised in that** a heat flow is measured as diffusivity and the mass flow rate is kept constant.
3. Method according to claim 2, **characterised in that** a density of the gas mixture is measured.
4. Method according to claim 1, **characterised in that** the calibration gas and the gas mixture is a hydrocarbon-containing gas mixture, in particular natural gas.
5. Device for determining a change in the heat value of a gas mixture with a sensor for determining a diffusivity,  
**characterised in that**  
the device has means for producing a constant mass flow rate and  
in that the device is calibrated to a reference value by means of a calibration gas with a known heat value, a deviation of the measured diffusivity from the reference value being a measure of the change in the heat value of the gas mixture.

6. Device according to claim 5, **characterised in that** the means for producing a constant throughflow rate produces a constant mass flow rate and in that the device is calibrated to a mass flow rate.
7. Device according to claim 6, **characterised in that** it has a means for determining the density of the gas mixture.
8. Device according to claim 5, **characterised in that** the means for producing a constant throughflow rate produces a constant mass flow rate and in that the device is calibrated to an energy flow rate.
9. Device according to one of the claims 6 or 8, **characterised in that** the means for producing the constant mass flow rate is a sonic nozzle.
10. Device according to claim 5, **characterised in that** the heat value sensor has at least two temperature sensor elements which are disposed successively in the flow direction, a heating element disposed therebetween and measuring means for determining a diffusivity from signals of the temperature sensors.

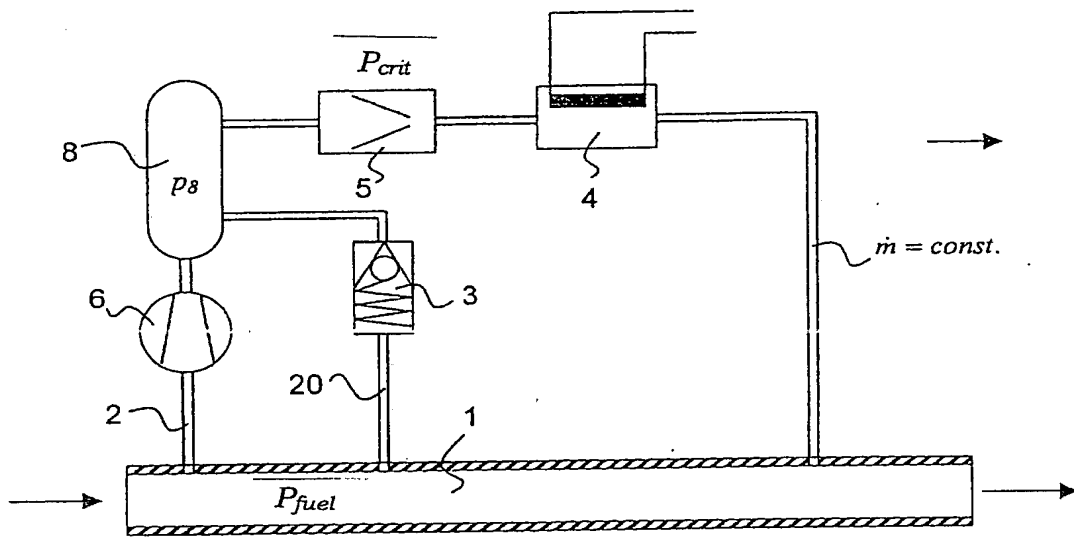


Fig. 1a

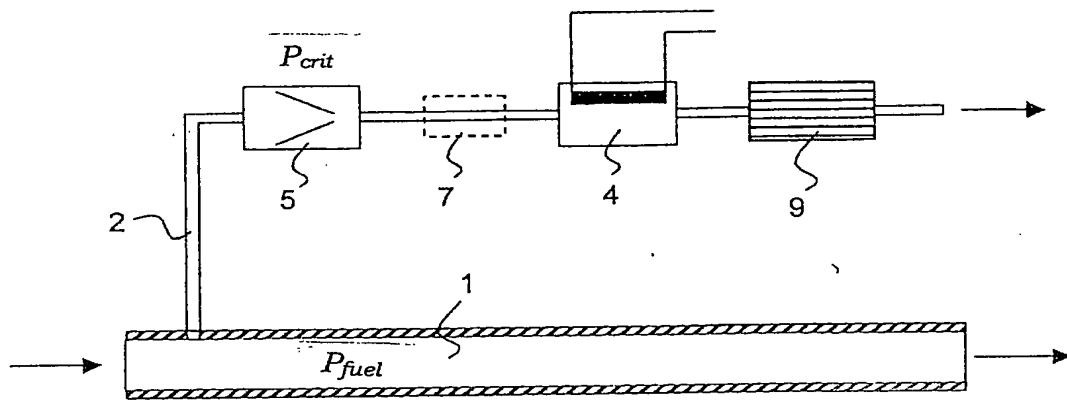


Fig. 1b

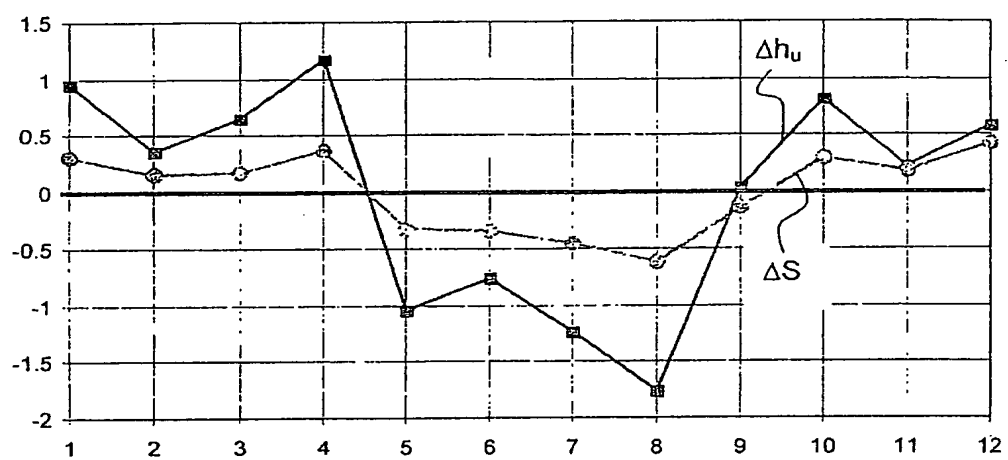


Fig. 2